White Paper on Minimum Flows and Levels and Indicator Species for Biscayne National Park

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ABSTRACT:

The South Florida Water Management District is required by state law to establish Minimum Flow and Level (MFL) rules for water bodies that have been identified as a priority (LECRWSP, 2000). Biscayne Bay, including the waters of Biscayne National Park has been identified as such a water body deserving of a high priority MFL. The purpose of the MFLs rule is to prevent significant harm to the Bay. Significant harm is defined as "the temporary loss of water resource function, which results from a change in surface or ground water hydrology, that takes more than two years to recover, but which is considered less severe than serious harm" (LECRWSP, 2000). As 2/3 of Biscayne Bay is encompassed within the boundaries of Biscayne National Park, the National Park Service has a keen interest and stewardship responsibility to assure a well founded MFL is established to preserve and protect Bay resources. As such, the Park describes the use of a salinity envelope or range that is based upon an understanding of current salinity conditions and how they relate to historic conditions and the use of a suite of organisms that have reasonable scientific information tying them to specific salinity conditions.

I. Executive Summary:

In 2000 the South Florida Water Management District (SFWMD) adopted the Lower East Coast Water Supply Plan. In this plan a schedule was laid out for the adoption of Minimum Flows and Levels for the areas in the Lower East Coast as well as for the renewal of water supply consumptive use permits. Consumptive use permits are to be upgraded from 5-year permits to 20-year permits. In order for the environmental areas to be protected from damage Minimum Flows and Levels (MFL) must be defined, as this is the legal mechanism to protect the natural system from damage due to existing and future consumptive use withdrawals (SFWMD, 2003). The district defines the levels for protection to be No Harm (the permitting standard), Harm, Significant Harm (MFL), and Severe Harm (irreparable damage) (SFWMD, 2003).

MFLs are the legal mechanism for the SFWMD to use to protect the natural system and avoid harm due to Consumptive Use Permitting (CUP). As previously substantiated by the National Park Service (9/02 interagency meeting hosted by the SFWMD) and reiterated now, the agency is supportive of the speedy development and implementation of MFLs for Biscayne Bay and Biscayne National Park. Specifically, the National Park Service recommends:

- Water should be allocated as a salinity envelope that changes over the year with rainfall and freshwater inflow. Use of a salinity range in bottom waters along the western shoreline of between 12 ppt and 28 ppt extending out 4000 meters in the dry season and 7000 meters during the wet season.

- Use of a suite of organisms as indicators, which are important to the Park, as well as to the people (visitors) who use the Park. Recommended indicator species linked to salinity, which historically and currently can support the distribution of salinity levels between 12 ppt and 28 ppt are as follows: the american crocodile (*Crocodylus acutus*), oyster (*Crassostria virginica*), spotted seatrout, (*Cynoscion nebulosus)*, silver perch, (*Bairdiella chrysoura)*, mojarras *(Eucinostomus)*, and red drum/"redfish" *(Sciaenops ocellatus)*.

- Establishing a peer review panel of scientists without a vested interest in current funding in the Bay to review the proposed MFLs for the Bay.

Furthermore, the National Park Service contends:

- That the Bay is already in Significant Harm because water resource functions have been lost therefore the MFL level is the current condition. If there were less water for the Bay, under current conditions then the bay would lose further water resource functions and water resources.

- The existing water flowing into the Bay is critical to sustain the health and vitality of Fish and Wildlife, including sustainability of western nearshore juvenile fish that otherwise could cease to grow and move on to other ontogenic habitats if existing freshwater inflows are depleted.

II. Background:

It is currently proposed by the South Florida Water Management District that in Biscayne Bay salinity will be measured as a surrogate for the health of the Bay and the organisms it supports. The National Park Service (NPS) believes that the use of salinity as a surrogate for the health of the Bay is reasonable application of the MFL rule. As such, NPS requests the MFL rule include a range of conditions throughout the year as a salinity envelope as established under Section III, Characterization, of this summary. NPS believes that the Bay is already in Significant Harm because water resource functions have been lost therefore the MFL level should be proposed as the current condition. If there were less water for the Bay, under current conditions then we believe that the Bay would lose further water resource functions and water resources so as to be irreparably damaged.

This document is in support of the use of a salinity envelop or range that is based upon an understanding of current salinity conditions and how they related to historic conditions and the use of a suite of organisms that have reasonable scientific information tying them to specific salinity conditions. As an addendum to this summary, background information is provided covering the organisms and methods NPS believes should be used as indicators. Our rationale for selecting these organisms is based upon their overall importance to the Park, as well as to users (visitors) of the Park. This document is intended to give some guidance and support to the use of a suite of organisms that are closely tied to salinity and have the most supporting information covering the range of salinity proposed by the SFWMD.

III. Biscayne Bay Characterization

A. Overview:

Biscayne Bay is a large, subtropical estuary located near highly urbanized areas, while also surrounded by more than 80,000 acres of agricultural lands. The Bay hosts a wide variety of diverse habitats, including, barrier islands, seagrass meadows, mangrove forests, sand and mud flats, and hardbottom communities. The Bay supports the offshore reef system as a major connected component and nursery area for juvenile fish and other wildlife. These habitats support hundreds of species of macroinvertebrates and ecologically and commercially important fish. Biscayne Bay waters are also home to several threatened and endangered species, including manatees, sea turtles, and crocodiles. The Bay's various habitats also support a multimillion dollar tourism and fish industry.

B. Salinity Gradient and Salinity Envelope of Biscayne Bay:

Biscayne Bay essentially extends from the northern boundary of Miami-Dade County to the southern boundary of Miami-Dade County, a distance of approximately 50 miles. The Bay is divided into two distinct sections by the Rickenbacker causeway. The area north of the Rickenbacker Causeway, the smaller of the two sections, has been highly modified by urban development, dredging, and shoreline hardening leaving this section of the bay essentially an artificial marine basin. The southern section of the Bay extends between the Rickenbacker Causeway and Cutter bank to the southern boundary of Miami-Dade County and Biscayne National Park. The lower two thirds of this section is within the established boundary of Biscayne National Park.

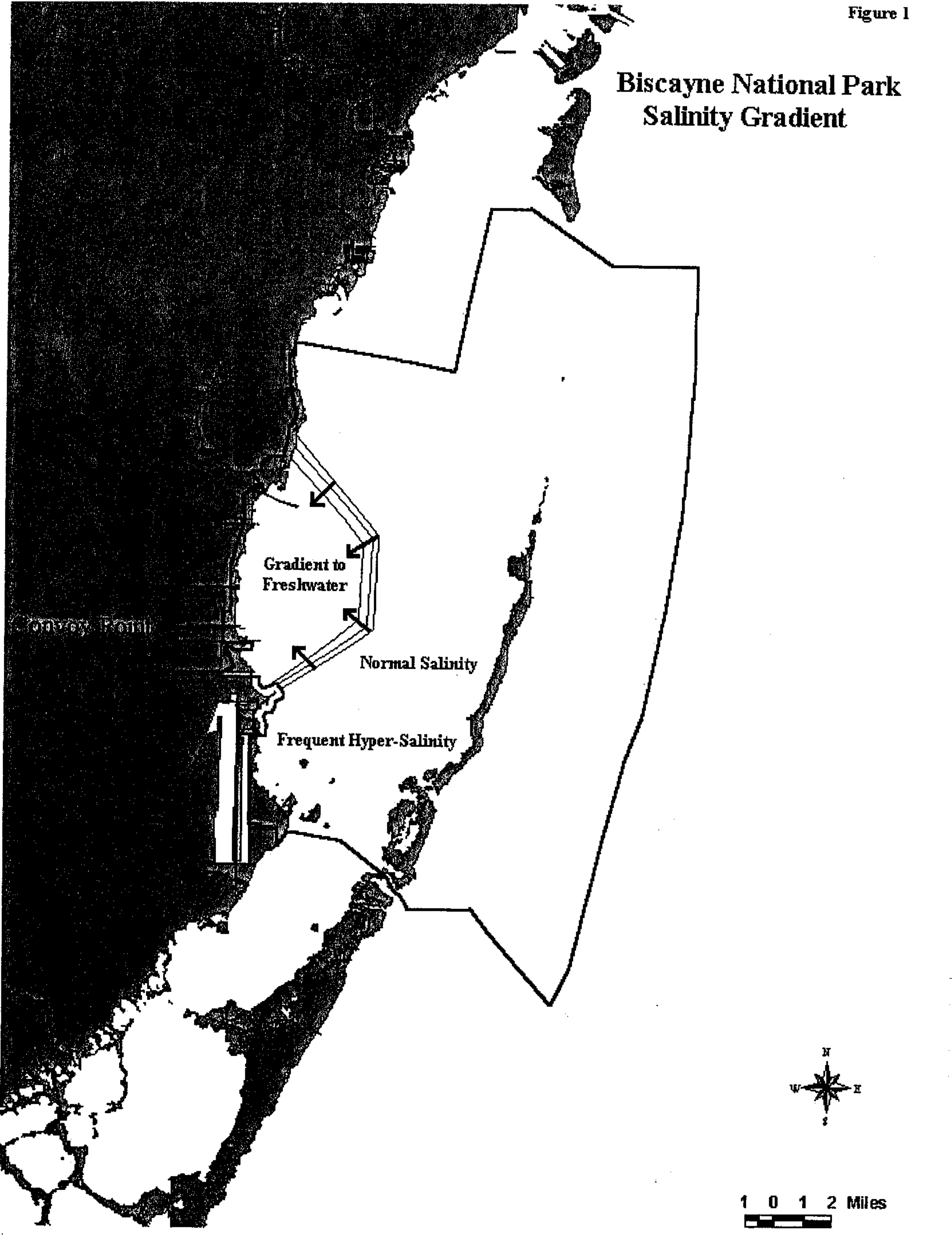
The Bay is isolated from offshore waters by a long series of islands, leaving tidal exchange to occur only across a shallow seven-mile shoal located between Key Biscayne and the islands of the Florida Keys. This area is known as the "Safety Valve." There are two large basins south of Biscayne Bay, Card and Barnes Sounds. These two basins in combination are the same or, slightly larger, than the southern portion of Biscayne Bay, and tidal exchange of these two basins is entirely through Biscayne Bay. Offshore water enters Biscayne Bay from the east flowing to the western shoreline where it splits, a small portion flowing to the north and the rest flowing south along the western shoreline. When the flow reaches the Turkey Point area it is forced to the east toward Pelican Bank and eventually to the northeast toward the Safety Valve area. Water flowing in and out of Card Sound is forced to the eastern side of the Bay by the water flowing south along the shoreline.

Freshwater enters the Bay through five drainage canals and a few natural groundwater springs near the western shore. Freshwater mixes with the tidal water flowing south lowering the salinity. Prior to the development of South Florida, freshwater was delivered to the Bay through the transverse glades to cause estuarine like conditions similar to what we see today. This input of freshwater significantly reduces the salinity along the western side of the Bay between Turkey Point and Cutler Ridge allowing this section of the Bay to be described as estuarine like.

Water flowing out of Card Sound and through the small tidal creeks transecting the island chain, constrains the influence of freshwater to the western side of the Bay. Isohalines (lines of equal salinity) run parallel to the long axis of the Bay (Figure 1), bending sharply to the southwest of Convoy Point, pinching out to almost hyper saline conditions south of Turkey Point. North of the Featherbed Banks, the isohalines bend to the west, but dissipate quickly due to mixing with the strong westward tidal flow of water entering the Bay over the Safety Valve. Seawater salinities approach that of seawater some 6000-8000 meters (4-5 miles) west of the mainland shoreline. Figure 2 shows a conceptual representation of the east-west salinity gradient (envelope) extremes that was typically observed in Biscayne Bay between 1970 and the late 1980's. In reality, the east-west salinity gradient would be described by some sort of second, or third, order polynomial that would oscillate within the two linear extremes (wet and dry seasons) noted in Figure 2.

Spatially, the eastward extent of lower salinity is shown in Figure 1 by the line of normal salinity. The 35 part per thousand isohaline, would extend, roughly, from Turkey Point passing just east of Pelican Bank curving slowly outward to 6000-8000 meters east of the mainland shoreline then paralleling the shoreline to the northern extent of the brackish zone some 1000-2000 meters north of the Featherbed Banks.

Figure 1


Biscayne National Park
Salinity Gradient
Gradient to
Freshwater
Normal Salinity
Frequent Hyper-Salinity
N
1 0 1 2 Miles

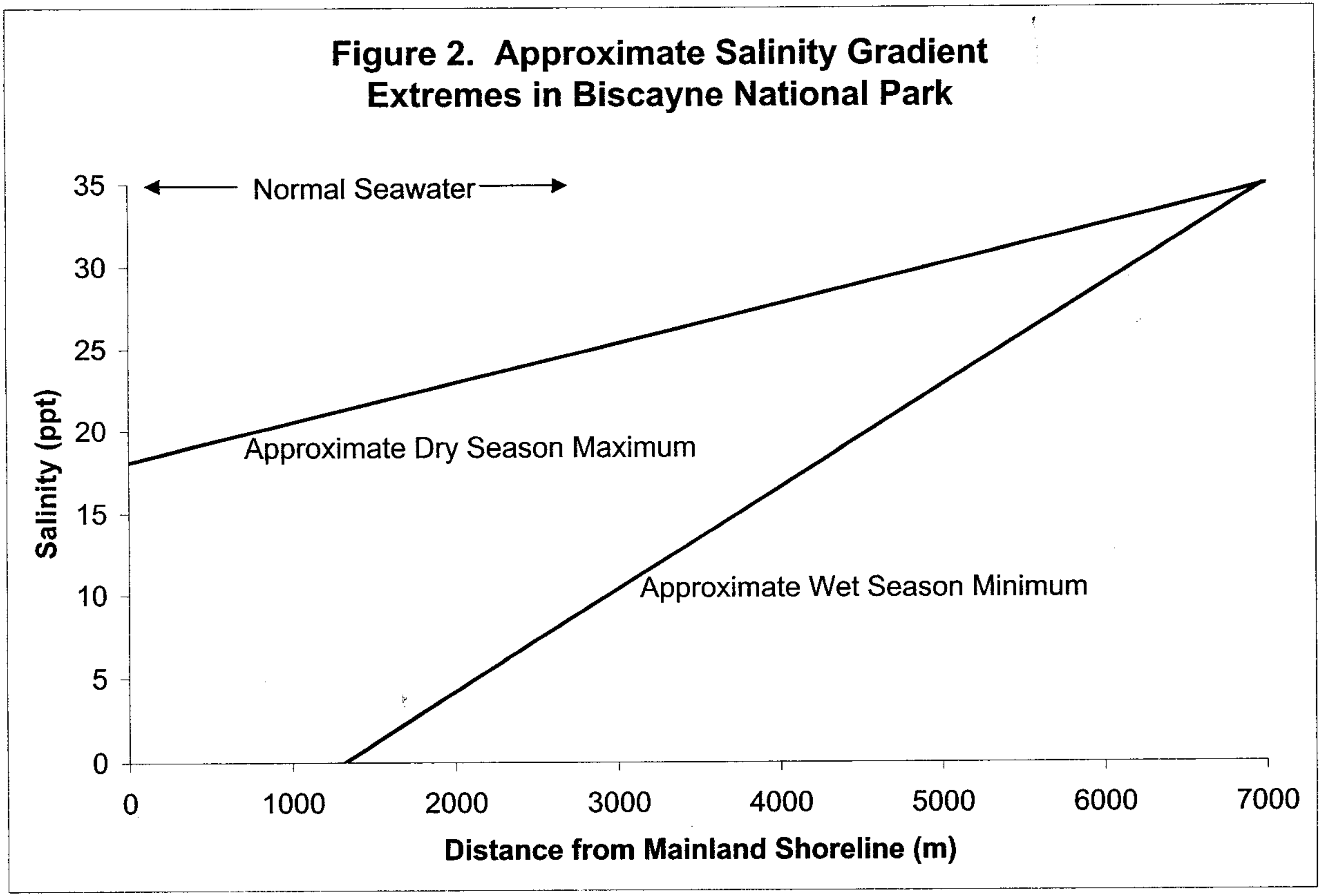


Figure 2. Approximate Salinity Gradient
Extremes in Biscayne National Park
Normal Seawater
Approximate Dry Season Maximum
Approximate Wet Season Minimum
Salinity (ppt)
35
30
25
20
15
10
5
0
0
1000
2000
3000
4000
5000
6000
7000
Distance from Mainland Shoreline (m)

ADDENDUM

Supporting documentation and scientific rationale substantiating the suite of organisms, or indicator species as recommended by the National Park Service, Biscayne National Park.

Recommended indicator species linked to salinity, which historically and currently can support the distribution of salinity levels between 12 ppt and 28 ppt are as follows: the american crocodile (*Crocodylus acutus*), oyster (*Crassostria virginica*), spotted seatrout, (*Cynoscion nebulosus)*, silver perch, *(Bairdiella chrysoura)*, mojarras *(Eucinostomus)*, and red drum/"redfish" *(Sciaenops ocellatus)*.

1. American crocodile, *Crocodylus acutus*

In 1975 the American Crocodile (*Crocodylus acutus*) was listed as endangered by the US Fish and Wildlife Service, the International Union for Conservation of Nature and Natural Resources, and the Convention on the International Trade in Endangered Species (CITES). Factors that have contributed to its waning population status include hunting, habitat loss and fragmentation, vehicle-related mortality, and depredation of eggs or young (USFWS, 1999). In addition, there has always been an interest in the study of any species that can potentially pose a threat to humans—especially with the increasing frequency of sightings and potential for interactions. For these reasons, *C. acutus* presents itself as an excellent candidate for long-term management opportunities and conservation efforts.

Ranging from the tropical coasts of South America through mainland Central America and up through the Caribbean Island region, the South Florida population represents the northernmost boundary of its distribution (Kushlan, 1988, Thorbjarnarson XXX)). Locally, *C. acutus* has taken up residence in three very different habitat regions: Turkey Point, the north end of Key Largo (Basin Hills area), and Everglades National Park (Gaby et al., 1985). At one end of the spectrum lies Turkey Point, a severely disturbed man-made cooling canal system with salinity and temperature ranges potentially stressful to crocodiles. On the other end lies Everglades National Park, a protected area of relatively undisturbed (except for hydrology) wilderness. Though the ability to exploit a variety of habitats drastically increases the potential for survival, Mazzotti et al. (1986) think it is likely that the S. Florida population is living close to the limit for "certain ecological tolerances." Factors considered limiting to population stability and growth, include: climate, hurricanes, population dispersion, nesting habitat, causes of nesting failure, juvenile survival, salinity, unnatural mortality, disturbance, and environmental contaminants (Kushlan, 1988, Mazzotti and Cherkiss 2004).

Despite their obvious differences, each of the three sites populated by *C. acutus* in S. Florida provides the basic habitat requirements in some form or another—deep secluded waters, protection from wave action, and high ground for nesting (Kushlan, 1988; Gaby et al., 1985, Mazzotti and Cherkiss 2004). The Turkey Point location consists of a series of long (270 km), shallow (0.5-2 m) cooling canals averaging 60 m in width and interspersed with berms of 1-5 m in height and 27 m in width (Gaby et al., 1985). Conversely, Florida Bay in Everglades National Park is characterized by mangrove shorelines interspersed with upland beach areas. Intermediate in disturbance the Crocodile Lake National Wildlife Refuge on North Key Largo, I primarily mangrove swamp with scattered canals from a illegal development that provide both deep secluded waters and upland nesting areas (Kushlan, 1988, Mazzotti and Cherkiss 2003). With such an array of habitat regimes to choose from, it is likely that basic chemical and physical parameters play a dominant role in delineating preferred habitat. Salinity, water flow/timing, and water temperature are three parameters that seem to have the greatest influence on the distribution and abundance of animals in estuaries in S. Florida.

While adults tolerate varying salinity, juveniles (< 200 g) are susceptible to osmoregulatory stress, and are likely to lose mass when maintained in hypersaline environments (Mazzotti et al., 1986). Ideally, *C. acutus* of any age will take up residence in areas of salinity ranging from 0-40 ppt (Mazzotti, personal communication), with most animal sightings occurring at less than 18 ppt (50 % seawater)and nest sightings at less than 27 ppt (75 %seawater) in Everglades National Park (Mazzotti 1999, Mazzotti and Cherkiss 2003). It has been suggested by several authors (Gaby et al., 1985, Brandt et al. 1995, Mazzotti and Cherkiss 2003) however, that when size classes overlap in space distribution in varying salinities is related to relative size class, with the majority of adults occupying fresh brackish areas and juveniles in areas of intermediate to higher salinities. This observation may be indicative of any variety of factors. The most likely explanations is that smaller crocodiles that occur where big crocodiles do run the risk of being attacked, killed and sometimes eaten (. Areas protected from wind and wave action mayo collect freshwater lenses atop the salt water layer after heavy rainfall, from which hatchling crocodiles can drink in order to regulate water balance before the onset of a fully functioning osmoregulatory system (Mazzotti and Dunson 1984). It has been confirmed by Mazzotti and Dunson (1984) that hatchling crocodiles can, in fact, gain mass in 100% sea water (35 ppt) when provided with a periodic source of brackish water (4 ppt) once a week. Though *C. acutus* sightings have occurred in areas of salinity reaching up to twice that of seawater (Brandt et al. 1995) as long as a a source of freshwater is close by.

Perhaps the most important control in regulation of salinity in these estuarine environments, is the quantity, distribution and timing of freshwater flow. "In general flow should peak at the end of the rainy season and continue discharging into the dry season. Freshwater flow should be adequate to maintain estuarine conditions (< 20 ppt salinity) into December or January in most years." (Mazzotti & Cherkiss, 1998. 2003) By restoring historic timing and flow of natural freshwater inputs to the bay, areas of hypersalinity are minimized and favorable conditions for the growth and development of hatchling *C. acutus* can be restored. The frequency of drought and flooding events are also potentially limiting to development. While droughts appear to be relatively rare in this area, flooding can be quite common and poses a great threat to clutch success. When flooding occurs, soils become saturated essentially suffocating the embryos (Mazzotti et al. 1988). With adequate water supply, estuarine conditions can be maintained and temperature becomes the limiting factor.

The distribution of *C. acutus* in S. Florida closely follows that of the mangrove swamp region, and is restricted by freezing temperatures (Kushlan and Mazzotti, 1989). In general, crocodilians have preferred body temperatures between (30-35C) and are often found in waters with a similar temperature range (Mazzotti et al., 1986). Likewise, nests have been observed at a range of temperatures varying from 28.6-35.0°C for marl nests, to 26.0-33.6°C for sand nests, with a maximum nest temperature of 37°C. While no lethal effects of high temperatures have been documented, temperatures in excess of 40°C have been shown to cause stress to hatchlings (Kushlan, 1988). Above this critical temperature animals spent an increased amount of time out of the water, decreased feeding activity, and failed to maintain mass (Mazzotti, 1986).

Salinity is a limiting factor in the distribution and abundance of American crocodiles in estuaries (Dunson and Mazzotti 1989). For this reason *Crocodylus acutus* makes an excellent indicator species for the determination of minimum flows and levels (MFLs). With an increased influx of freshwater, the natural estuarine conditions of the area should be restored. This does not imply that *C. acutus* populations will grow or even expand their habitat area as a result of the MFL modifications, only that optimal conditions that were known to have existed in the bay—conditions that supported *C. acutus* in the past—will once again be re-created.

2. American Oyster, *Crassotrea virginica*

(a) Background & Distribution

The oyster is one of the most well-studied marine invertebrates due to its economic significance, the nursery habitat the bioherm provide, and the navigational hazards they pose to nearshore craft (Meeder, 2001). Oysters are sessile, filter-feeding organisms which prefer estuarine conditions with low salinity and food bearing water currents (Meeder, 2001).

Crassotrea virginica occurs along the Atlantic Coast from the Gulf of St. Lawrence, into the Gulf of Mexico, and around to the Yucatan Peninsula (Galtstoff 1964). Historically, Biscayne Bay supported an abundant oyster population, with active oyster fisheries until the 1920's (Meeder, 1997). Major anthropogenic changes in the northern bay caused an increase in salinity, and therefore, resulted in the loss of this industry (Meeder, 2001). This also occurred in the Ten Thousand Islands area of Florida (Tebeau 1991). In other areas of the southeast United States, levee construction and deep channel dredging, have also been reported to kill oyster bioherm by preventing freshwater flows and allowing saltwater intrusion, respectively (Meeder, 2001).

Presently, the abundance of oysters is very low in Biscayne Bay and their distribution scattered (Meeder, 2001). According to Meeder (2001), live oysters were only found on mangrove roots along the shoreline and up into tidal creeks approximately 100 meters. Though review of bioherm strata shows evidence of oyster populations at nine locations, none of these sites are active at present (Meeder, 1999).

(b) Relationship to Freshwater Flows and Salinity

The American oyster is a euryhaline species found in near freshwater to normal marine salinities. This relationship has been well established and documented in numerous studies throughout the southeastern United States from North Carolina (Grave, 1905) to Florida (Pearse and Wharton, 1938). Extensive oyster shell beds have been reported in Northern Biscayne Bay (Harlem, 1979), with lesser oyster populations observed in central and southern regions of the bay. Meeder (1999) also found bioherm strata at several tidal creeks along the western shoreline. This study discovered a sudden die off associated with loss of freshwater discharge and the resulting rise in salinity (Meeder, 2001). Increased salinity exposes oysters to increased rates of predation and parasitism making brackish waters a safer and more suitable habitat (Grave, 1905). Butler (1954) also found that salinity most influenced oyster location. He reported that as fouling increased with salinity, oyster abundance and spatfall were affected negatively.

Though *C. virginica* prefers low salinity estuarine habitat, it cannot withstand totally freshwater. Eggs and spermatazoa need salinities of at least 7.5ppt to function properly (Stenzel, 1971) and spat need water of 5ppt or greater to develop successfully (Meeder 2001). Burrell (1986) found that larval development is optimal at 25-29psu and best adult growth at 14-30psu. There is sufficient evidence to delineate a salinity range of 5-20ppt as optimal conditions for the American oyster. Meeder (2001) suggests a regime of 5-15ppt during the wet season and 10-19ppt in the dry season. Studies in other parts of the southeast, as previously cited, support this salinity range as well.

In addition to being good indicators of salinity regime, oysters and the reefs they produce provide a unique and ecologically-important habitat within the bay which supports other resident species such as small fish, crabs, polycheate worms, and amphipods (Bahr, 1981). Alleman et al. (1995) mentioned that historically freshwater inflows supported a more diverse fish population than currently present. Browder and Moore (1981) presume that the fish populations have suffered due to the lack of this habitat feature. Bioherms need more specific conditions to develop than the individual oyster. As well as salinity, temperature, tidal range, and circulation patterns strongly affect oyster reef development and growth (Meeder, 2001). Oysters colonize where water currents prevent sediment deposition, provide clean substrate for spat settlement, and retain organic detritus in suspension (Meeder, 2001). With the loss of freshwater flows to Biscayne Bay all these factors for successful oyster recruitment were affected. Without freshwater sheet flow particulate organic carbon loads are reduced, the main food source for filter feeding organisms. Also, increased siltation and anthropogenic-based nutrient loads resulted in algal cover, making substrate unsuitable for larval colonization and oyster filtration processes difficult (Meeder 2001). Though all these contributed to the failure of oyster reefs and continue to retard their development, increased salinity has greater ramifications to oyster populations (Bahr, 1981).

It is evident, after review of the data, that Biscayne Bay historically supported the necessary habitat and conditions for successful recruitment, development, and growth of

C. virginica. Due to the low salinity dependence of the American oyster for suitable habitat, proper growth and development, and protection from predation and parasitism, it lends itself as an appropriate indicator of a proper salinity regime for the bay. The development of bioherms would indicate restoration of historical conditions and though this is not a goal of the MFL program, restoration would signal success of freshwater flow management to Biscayne Bay as suggested by Meeder (2001).

3. Blue Crab, *Callinectes sapidus*

(a) Background and Distribution

The blue crab is abundant throughout its range in the Atlantic Ocean from Nova Scotia to northern Argentina. *Callinectes sapidus* serves as predator and prey in temperate to tropical marine waters and inhabits a variety of bottom types within these. Rapid growth, high fecundity, and a life span of 1-3 years characterize the blue crab (Steele and Bert, 1994). *C. sapidus* also proves to be an opportunistic omnivore feeding on fish, aquatic vegetation, mollusks, annelid worms, and other crustaceans (Murphy et. al, 2001).

(b) Salinity Tolerance and Needs

The life cycle of *C. sapidus* can be easily divided into offshore and estuarine phases. As most decapods, the blue crab moves to specific habitat of varying salinities to fulfil life cycle needs such as spawning, mating and/or molting (Steele and Bert, 1994). These moves from high-salinity water to low-salinity water, and vice versa, help the crab to maintain optimal seasonal temperatures, find increased food sources, and avoid predation (Steele and Bert, 1994). The blue crab enters low-salinity waters to mate and molt, and it is here where the zoeae hatch. A narrow margin of 22-28ppt is needed for normal egg hatching, while post-larval crabs have no critical salinity range (Hill et. al., 1989). Steele and Bert (1994) also reported that, in general, juvenile crabs occupied low-salinity waters 0-10ppt and in high-salinity waters of greater than 30ppt the population was almost exclusively mature adults. Marine waters offer increased dispersal capabilities, successful larval development, reduced predation, and a decrease in osmoregulatory stress (Hines et al., 1987). Females migrate to these waters after mating while males tend to remain within the estuary possibly to avoid cannibalism during molting (Hines et. al., 1987). Steele and Bert (1994) also noted a "difference between the sexes in osmoregulatory capability". In yet another study, data supported that *C. sapidus* could survive acute salinity changes due to the osmoregulatory capacity of the species (Kinsey and Lee, 2003).

Though salinity plays an important role in the life cycle of *C. sapidus*, distribution is determined by the interaction of multiple factors such as food abundance, temperature, and predation. The blue crab is a reproductive selected strategist species characterized by early attainment of sexual maturity and short life span. These species exhibit large inter-annual fluctuations in abundance due to a variety of chemical, physical, and biological components within the ecosystem (Guillory, 2003). Juvenile and adult growth is regulated by water temperature. Growth will only occur in waters above 15 degrees

Celsius. At temperatures below 10 degrees Celsius, *C. sapidus* will seek refuge in deeper water where they will bury themselves and remain in turpor for the winter (Zinski, 2003). Temperatures above 33 degrees Celsius are lethal to the blue crab (Zinski, 2003). With so many factors affecting distribution and abundance, the blue crab would prove difficult to monitor for environmental shifts related to decreased freshwater inflow to the bay.

In various studies it has been found that blue crabs exist in highly variable salinities ranging from 0-34ppt (Hill et. al., 1989). It has also been shown in laboratory studies that "salinity had no effect on growth rates…"(Guerin et. al., 1997). It is evident, through available data, that *C. sapidus* is highly adaptive and can survive and grow in varying conditions and habitats. Due to its adaptive nature, *C. sapidus* would not indicate the proper freshwater flows needed to maintain the integrity of the bay. Also, the data and literature specifically pertaining to blue crab abundance and distribution within the bay is insufficient to prove historic and existing populations. Without this information, the importance of the blue crab to the overall ecosystem health is questionable and the extent of change in presence/absence based on salinity regime difficult to determine.

ABUNDANCE PATTERNS OF THREE FISH TAXA ALONG A SALINITY GRADIENT: AN EXAMINATION OF DATA FROM BISCAYNE BAY

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Introduction

Smith (1896) provides the earliest documentation of the fishes of Biscayne Bay. He listed 95 fish taxa with annotations for 22 regarding their seasonality, abundance and fisheries, if any, in bay waters. The presence of several species of drum (Family Sciaenidae), and the characterization of some as either abundant or common, is particularly revealing of more estuarine conditions over 100 years ago (Serafy et al. 2001). For example, Smith (1896) referred to red drum (*Sciaenops ocellatus*) as "Abundant at all seasons" and to black drum (*Pogonias cromis*) as "Found near oyster beds in the bay. Common." Only two of the eight drum species that Smith (1896) listed (i.e., spotted seatrout, *Cynoscion nebulosus*, and silver perch, *Bairdiella chrysoura*) have appeared in recent trawl studies (i.e., those conducted in the last 30 years). This analysis is a re-examination of data described by Serafy et al. (1997) with a focus on revealing the "salinity distribution" of juvenile spotted seatrout, silver perch and mojarras of the genus *Eucinostomus* that were collected from Biscayne Bay during research cruises conducted from 1993 to 1994.

Fish Collection

Juvenile fishes were collected from eight, seagrass-dominated study sites in western Biscayne Bay over 14 consecutive months aboard a commercial, live bait shrimp fishing vessel equipped with paired, rollerframe trawl nets (for details see Serafy et al. (1997). Salinity was measured, along with water temperature, depth and area swept, during fish sampling. All fishes were identified, when possible, to species, enumerated and measured for total length.

Data Treatment

Species-specific fish densities were calculated and expressed as numbers per 1000 m^2. Two abundance metrics were calculated for selected species along a salinity gradient: (1) the proportion of catches that were positive for species x; and (2) the magnitude of catch, referred to as fish concentration, when species x was encountered (i.e., when catch > 0). This was achieved by designating each fish catch to one of five, 5-psu salinity (S) bins that covered the range observed and that were each represented by at least 10 catches: (1) $S \leq 15$; (2) $15<S\leq 20$; (3) $20<S\leq 25$; (4) $25<S\leq 30$; (5) $30<S\leq 35$. Proportion positive and mean fish concentration values were then each plotted to reveal patterns along the above gradient of salinity intervals.

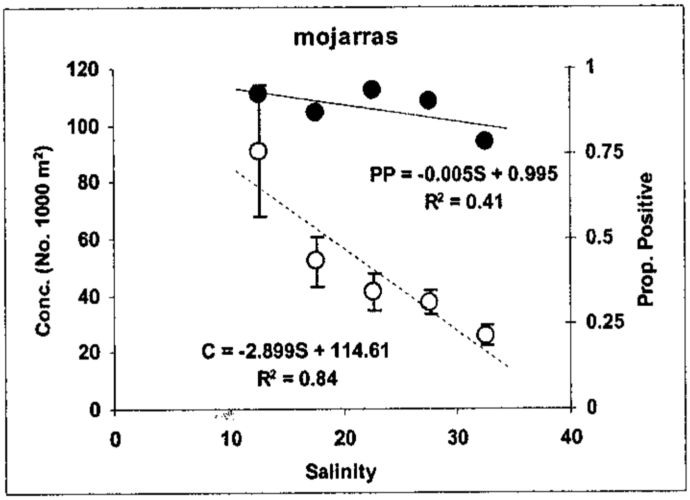
Results

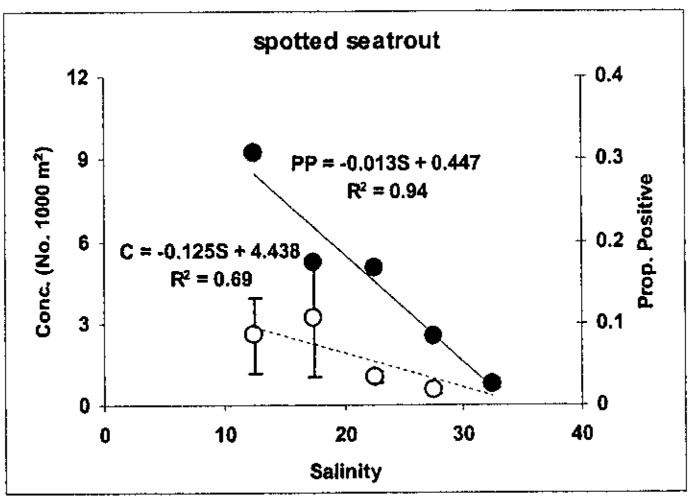
Figures 1A-C indicate the strength and direction of abundance patterns for three fish taxa: (1) eucinostomid mojarras (*Eucinostomus* spp.); (2) juvenile spotted seatrout; and (3) juvenile silver perch. Linear declines in both abundance metrics for all three fish taxa were evident, particularly for the two sciaenids.

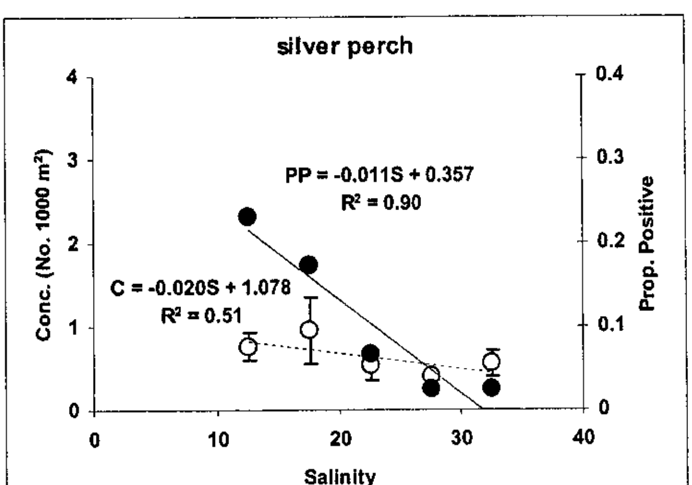
Conclusions

Clearly, the fish abundance metrics examined here are not driven solely by salinity -- numerous other factors (e.g., seagrass density, water depth) combine with salinity to define and influence the seagrass habitats that we sampled as well as their fish assemblages. Nevertheless, the patterns of abundance decline revealed here suggest that further reductions to Biscayne Bay's freshwater flow, which will in turn increase salinity levels over western seagrass fish nursery habitats, may lead to further reductions in the abundances of species that apparently prefer intermediate-salinity conditions. Our results bear a strong resemblance to those of Campos (1985, see page 42) who found spotted seatrout and mojarra catch rates to decline at high salinity levels. While it is premature to conclude that reduced freshwater flow will have direct, deleterious impacts on the early life stages of the spotted seatrout and silver perch, due caution is warranted, particularly for the former which supports a valuable local fishery. Although the mojarras have little or no commercial value, their ecological importance should not be underestimated because they are common constituents in the diets of numerous predatory fishes, such as adult spotted seatrout, gray snapper, *Lutjanus griseus*, great barracuda (*Sphyraena barracuda*, (Hettler 1989; Schmidt 1989).

References


mojarras
Conc. (No. 1000 m²)
Prop. Positive
Salinity
PP = -0.005S + 0.995
R² = 0.41
C = -2.899S + 114.61
R² = 0.84
120
100
80
60
40
20
0
1
0.75
0.5
0.25
0
0
10
20
30
40


spotted seatrout
Conc. (No. 1000 m²)
Prop. Positive
Salinity
PP = -0.013S + 0.447
R² = 0.94
C = -0.125S + 4.438
R² = 0.69
12
9
6
3
0
0.4
0.3
0.2
0.1
0
0
10
20
30
40


silver perch
Conc. (No. 1000 m²)
Prop. Positive
Salinity
PP = -0.011S + 0.357
R² = 0.90
C = -0.020S + 1.078
R² = 0.51
4
3
2
1
0
0.4
0.3
0.2
0.1
0
0
10
20
30
40

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